

THE SOLAR ECLIPSE OF JUNE 17, 1909.—Observations of the contacts, during the solar eclipse of June 17, were made by Father Rigge, at the Creighton University Observatory, Omaha, and showed that the phenomena actually occurred a second or two earlier than the computed times. At first contact the difference was 2.02s., and is trustworthy, but at the last contact a difference of 18.4s. was observed, and may largely be due to the extremely bad conditions under which the observation was made, the sun being within fourteen minutes of setting (*Astronomische Nachrichten*, No. 4340).

RECENT IMPROVEMENTS IN THE INTERNAL-COMBUSTION ENGINE.

I.

A SURVEY of the progress made during the last twenty-five years in almost any field of engineering work would show an immense advance. Even during the past ten years very considerable progress has been made in certain branches of applied science, and in none of them to a greater extent than in the internal-combustion engine. We need not in this comparison claim the gun as a form of internal-combustion engine, though we are naturally entitled to do so. We may leave lethal weapons aside, and think only of the remarkable development of the reciprocating internal-combustion engine, and of the many changes it has brought about in our times. It has revolutionised cross-country transit. It has given us the long-deferred, but now actually achieved, victory called the "conquest of the air." It is extraordinary to think of the numbers of men who have spent ingenious years in seeking a solution of the problem of flight. The solution has come in the unexpected form of a pair of long, sail-like arms, driven forward by a small high-speed internal-combustion engine. This simple form of design, which, owing to the relation between centre of pressure and angle of tilt, seems to be naturally stable, bids fair to be adopted in a great output of flying machines shortly to be constructed. The hardly less novel, but less interesting, dirigible balloon owes the whole of its dirigibility, whatever that may amount to, to the internal-combustion engine.

Less startling, but of considerable material importance, is the utilisation of "waste heat" in our coal- and iron-producing areas. Our coal supply is admitted to be limited, and there seems to be at least an indication that at the present rate of consumption mankind would, in a few centuries, have to be prepared to turn its attention to the unlocking of some other form of stored-up energy, perhaps a radio-active one. It is not too much to say, however, that if the power available from the waste gases of blast-furnaces and coke-ovens in this country—and the amount can hardly be less in the aggregate than 1,000,000 h.p.—were put to use, the saving in the coal consumption might perhaps give us another half-century or two in which to look about for some substitute for coal.

In writing of what has been already achieved, we have to remember that we are only yet at an intermediate stage in the development of the internal-combustion engine. The internal-combustion engine gives us a bigger return for heat put in than any other known form of engine. We cannot imagine the development of the future "going back," so to speak, on such an advance as that. The internal-combustion engine must come, and existing steam engines be replaced. This means the supersession of the steam turbine, and may therefore seem to suggest a retrograde step, since the rotary engine is mechanically an improvement on the reciprocating one. We have to remember, however, that evolutionary processes sometimes take a step backwards to an earlier form in bringing forward the latest and most developed creation. No one would look on any reciprocating engine as a final improvement on a rotary one, even although, as is now the case, large gas engines are capable of so uniform a rotary motion that alternators are easily driven by them in parallel—the standard test of excellence in this respect. The day of the gas-engine turbine must come. Numbers of men are working at the problem which it presents; but little has as yet been published as to the result of their labours—an indication that the many difficulties are not yet mastered.

The present stage in the development of the internal-combustion engine is a convenient one at which to summarise briefly what has been done in regard to its improvement. We therefore propose in this and the succeeding articles of the series to state the problem and the lines on which, with such a striking measure of success, its solution has been attempted.

The problem can be stated in a very simple form. Given one pound of carbon of, say, 12,000,000 ft. lb. calorific value, which is a normal estimate, find how to obtain the largest possible amount of useful power. So far this energy has always been liberated in the form of heat. This heat has been given to some body which, by its subsequent cooling, can give out mechanical energy—such a body is a mass of gas or vapour. Let us assume that a mass of gas is chosen as the working medium. It is obviously desirable that the heat liberated should be absorbed as completely as possible by the gas, but in investigating whether this has been effected one at once meets with a check. To tell whether the whole of the 12,000,000 ft. lb. of heat energy has reached the gas, we may either look out for possible chances of heat leakage or may measure the amount of energy in the gas at the end of the operation. But to do the latter is practically impossible, for we do not know the specific heat at high temperature of any gas, and to do the former is extremely difficult, owing to the very short time the heat transference usually takes, and owing also to our lack of knowledge as to the temperature of metal or other surfaces in contact with, and enclosing, the gas. Many attempts have been made to ascertain what happens to the heat liberated, and much has been written on such topics as "dissociation," "after-burning," and "increasing specific heats." There would be no difficulty in filling the whole of the allotted space with a discussion of the various experiments that have been made and theories that have been built on this subject, but as many other matters have also to be dealt with, and as the author has already written on this topic elsewhere,¹ he does not now propose to go into the matter at length.

Briefly summarised, the result of gas-engine experiment is to establish that only about 50 to 55 per cent. of the heat energy known to be liberated is accounted for by multiplying the measured rise of temperature by the commonly accepted figure for the specific heat at constant volume. The same ratio of 50 to 55 per cent. was found for all sizes and shapes of containing vessel, and for all mixtures of gas. This constancy at once disposed of the theory that the "suppression of heat" was due to dissociation, as such an effect would naturally be dependent upon, and increase with, the increasing temperatures due to the richer mixtures. Equally it showed that the cooling of the gas by convection currents, radiation, and conduction to the walls of the containing vessel was an inadequate explanation. The suggestion of the French physicists, MM. Mallard and Le Chatelier, that the effect must be due to increase of specific heat with temperature was open to precisely the same objection as that of dissociation, and involved values of the instantaneous specific heat much in advance of what was then thought likely. It is now generally recognised that the real explanation of the apparent suppression of energy is due to a combined cooling effect and rise of specific heat. "After-burning" is now generally believed, as a result of many tests, not to occur in normal circumstances. With a weak mixture the time of explosion, and therefore of cooling, is a long one, so that the cooling loss has time to become considerable, and this compensates for the lesser degree to which the theory of increasing specific heats is effective for these weak mixtures and low temperatures.

The constancy of this apparent "loss" made it clear that no great improvement in the internal-combustion engine could be looked for in any increase of pressure and temperature in a gaseous mixture of given strength. We cannot alter the specific heat law of a substance. We might, perhaps, alter our working medium, which now for the most part is nitrogen, but no other gas is so cheap or so easily obtained; but we may vary the part of the temperature scale over which we work, and, within limits, we may affect the cooling loss by altering the shape of the containing vessel or cylinder. Experiments have shown

¹ "The Internal-combustion Engine" (Constable and Co.)

that the less the ratio of cooling surface to volume the less the proportionate cooling loss, and therefore the greater the amount of thermal energy converted into work.

Engines that have "pockets," that is, cavities in their walls, in which to contain ignition plugs or valves, are known to be less efficient than those that have not. On the other hand, it must not be forgotten that although this loss of efficiency exists, it is at any rate partly compensated for by the greater flexibility of the engine. It has been found, particularly in motor-car engines, that "pockets" have a very useful effect in enabling very variable mixtures to fire. The ignition plug is placed in a pocket so that, even when the mixture is a very poor one, there will be sufficient local "richness" in its neighbourhood to start an explosion which, once started, proceeds throughout the mass of the gas. Another fact which may have the result of increasing "pocketing" is the recently measured temperature limit for pre-ignition. Prof. Hopkinson has found that surfaces below 700° C. will not cause pre-ignition, whilst those above may do so—if above 750° C. they are pretty sure to do so. Now the surfaces most likely to rise to such temperatures are those remote from the cooling water in the jacket. The projecting end of an ignition plug is such a surface, and when exposed to the full heat of the explosion, as it is when the plug is not pocketed, pre-ignition may well occur. Prof. Hopkinson has shown also that when once a point of metal gets hot enough to cause pre-ignition, the very ignition of the flame in its neighbourhood will tend to cause the temperature to rise still higher, so that the phenomenon grows on itself and persists. It is not everyone who is moved, however, by such considerations, and we have lately seen in the design of the new Daimler engine a clearly expressed intention to avoid pocketing and its consequent loss of efficiency without any apparent fear of introducing other features much less desirable. It is only fair to say, however, that this engine is still on its trial. The ideal plan would appear to be to pocket the ignition plug but not the valves, and so combine the good features of both systems.

This frank abandonment of the highest possible efficiency by those who use pocketed engines brings us naturally to the consideration of thermal efficiency and the laws that regulate it. One may say at once that the theory of the internal-combustion engine has, until lately, been in a chaotic condition. The standard of efficiency for gas engines laid down by an influential committee had been found subsequently to be unsatisfactory as giving an impossibly ideal figure. That such remarkable progress in invention and mechanical perfection should have gone on side by side with this uncertainty as to the true standard of performance has often struck observers with astonishment. The considerable scale of the practical side of gas-engine development is illustrated by the fact that of one well-known make of double-acting gas engines alone, no fewer than 247 engines of an aggregate output of 308,000 h.p. have been built or ordered during the last six years. This corresponds to the large figure of more than 50,000 h.p. per year for only one of the many firms engaged on the work. At the moment the total capacity of gas engines in use must be well over 2,000,000 h.p., and of petrol engines much more than 1,000,000 h.p., making a total of more than 3,000,000 h.p. in internal-combustion engines. These are striking figures. Some of these engines and plants work with solid fuel and some with liquid. It would not be possible, even were it considered desirable, to use liquid fuel to the entire exclusion of any other. The present output of petroleum over the whole world is only 20,000,000 tons, a very small figure compared with the yearly consumption of 800,000,000 tons of coal. Unless, therefore, fresh supplies of oil are discovered, there can be no development of the internal-combustion engine which would lead to liquid fuel replacing solid fuel altogether.

In the articles that will follow, the author intends to deal with the problem of efficiency, taking into account the now established increase of specific heat with temperature, its effect on rating, and the recent practical improvements in the design and operation of gas engines and gas-producing plant.

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CONTINUATION SCHOOLS AND NATIONAL EFFICIENCY.

AMONG the numerous problems now confronting English educational administrators, probably the most urgent is that discussed in the valuable and exhaustive report on attendance at continuation schools recently issued by the Consultative Committee of the Board of Education. To some extent the report covers similar ground to that traversed in the educational sections of the Majority and Minority Reports of the Poor Law Commissioners, arriving at almost identical conclusions.

The essential features of the problem are as follows:—Under the existing Education Acts, children must attend school from their fifth to their fourteenth birthdays, subject to certain exemptions (prescribed by local bye-laws) during the last three years of the school period. Local education authorities may grant (a) total exemption from school attendance at eleven years of age to children engaged in agriculture, (b) full-time or half-time exemption, or both, to children between twelve and fourteen. The "leaving age" is generally twelve or thirteen. Full-time attendance at a day school until fourteen is now compulsory over areas comprising about 22 per cent. of the population of England and Wales. The committee estimates that in the year 1907, the latest year for which full statistics were available, there were about 211,000 children under fourteen years of age who had obtained full-time exemption from day-school attendance. Of these, only 40,500 were attending evening schools in the year 1906-7, leaving 170,500 children between the ages mentioned not attending any form of week-day instruction. Further, the estimated population of England and Wales between the ages of fourteen and seventeen is 2,022,300. After deducting from this the number attending elementary, secondary, technical, or evening schools, it is estimated that nearly 1,498,000 (or approximately 74 per cent.) boys and girls between the ages of fourteen and seventeen are not receiving any form of scholastic instruction. We have therefore, about 1,668,500 boys and girls from twelve to seventeen years of age whose formal education has entirely ceased for the time being. Recent inquiries in London and Glasgow render it highly probable that a very large proportion, if not the majority, of these boys and girls, if in wage-earning occupations, are employed in purely mechanical work of a monotonous, uneducational character, of no industrial value when the child becomes an adult.

Under these conditions the education, such as it is, given in the elementary school is being rapidly forgotten. The boys and girls are almost entirely exempt from parental control; they are falling victims to the prevailing passion for cheap amusements and to the attractions of the streets. Any slight gleam of intellectual aspiration which may have been aroused in the elementary school is rapidly being extinguished. The enormous sums spent by the State upon the elementary education of these young people are almost entirely wasted. All that remains is a certain facility in reading, writing, and very elementary arithmetic. Even if the boys are definitely apprenticed to a trade, matters are not much better. Under the present industrial conditions, involving the minutest possible specialisation in the works, the employer cannot possibly afford, even if he wishes, to give the boy the all-round training which was given by apprenticeship under the older industrial régime. Industry now requires, in addition to manual dexterity, a general industrial knowledge and a trained intelligence which will enable the worker to adapt himself to ever-changing industrial conditions; but this knowledge and training are not now given by apprenticeship. Hence, an education outside, but concurrent with, the workshop is essential. A further important factor is that even if a boy be apprenticed to a skilled trade, he is generally not taken on until about sixteen years of age. The intermediate years, between leaving school at thirteen and commencing apprenticeship at sixteen, are usually spent in "blind alley," uneducational occupations such as that of errand boy, van boy, messenger, &c.

For many years to come the formal education given to

1 Report of the Consultative Committee of the Board of Education on Attendance, compulsory or otherwise, at Continuation Schools. Board of Education, White Paper. Cd. 4757. (London: Wyman and Sons.) Price 1s. 6d.